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Title of Paper

Measuring R&D in the Era of Revolution Industry 4.0: Issues and Challenges, A Case Study of Indonesia

Abstract

In Revolution Industry 4.0 era, -- which is characterized by the transformation of business models by enabling the fusion of virtual and real words and the application of digitization, automation, and robotics in manufacturing--, innovation becomes essential key success factor for competition and company's business development. One of the enabler factors of innovation is Research & Development (R&D). Given today's competitive business environment, R&D has become a critical activity. In order for policy makers, industry bodies and the private sector to maximize the returns from R&D activity it needs to be measured effectively. Measuring R&D in Indonesia has proved to be very challenging; this paper highlights some of those challenges and issues based on experiences from a BPS R&D Pilot survey and a literature review.

In 2017, BPS conducted a Pilot survey to collect R&D data. The collection instrument was developed through using best practice survey development processes including but not limited to cognitive testing, conceptual testing, and observational testing. Within this systematic development framework, BPS was able to develop a sound survey instrument which enabled collection of some core indicators related to R&D activities; for example, indicators to support measurement of the Sustainable Development Goal (SDGs) 9: "Build Resilient Infrastructure, Promote Inclusive and Sustainable Industrialization and Foster Innovation". However, there are remaining some issues, either in terms of concepts, definitions, coverage, and method of data collection which will need to be refined for future iterations of the survey.

I. Contents

II. Introduction

Science, Technology, and Innovation is recognized not only as a driver of National Economic Development, but more importantly as a key contributor to poverty reduction and as a central component to achieving sustainable development[1]. Economic development in the age of industrialization has been heavily dependent upon the overexploitation of natural resources; given this, policymakers have been looking for different strategies before irreversible damage to the environment occurs. . One of effective ways to enhance economic development in the long term is through improvements in productivity. It is widely acknowledged that investment in innovation is one of the major drivers of productivity growth (with R&D expenditure targeting being one of a mix of innovation policies). R and D has potential to contribute to the SDGs goals. In particular, it has explicitly been mentioned as targets in Goals 9 (9.5.1, 9.5.2 and 9.b.1). By 2030, Target 9.5: Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending. The development and availability of data sources and tools is indeed expected to boldly contribute to the SDGs target as a means of SDGs implementation. Indonesian Government has decided all the SDGs indicators will be monitored up to sub national level (province and regency) in order to achieve the SDGs targets.

In 2015, World Economic Forum introduce the term Industrial Revolution 4.0. The term is developed from the third industrial revolution which started in the 1980s and means the transformation from standard to computerized technologies. The Industrial Revolution 4.0 is more advanced than the 3.0, it is combined both technology and society to establish more efficient human life. Together with Industrial Revolution 4.0 came technological

[1] Science, Technology, and Innovation Policy –STIGAP for the Asia Pacific Region, 2013

advancements such as robotics, 3D printing, distributed digital ledgers, Internet of Things, Artificial Intelligence, nanotechnology, and many more life-changing innovations. These technologies are being implemented in our daily lives.

In the Era of Revolution Industry 4.0, -- which is characterized by the transformation of business models by enabling the fusion of virtual and real words and the application of digitization, automation, and robotics in manufacturing--, innovation become essential key success factor for competition and company's business development. One of the enablers of innovation is Research & Development (R&D) activities. The conduct of research and development (R&D) has become a very important factor to enable innovation, hence productivity improvements and growth; R&D and innovation serve as an engine for economic growth and sustainable development in both advanced and developing countries such as Indonesia. Policy-makers, therefore, require trustworthy indicators to benchmark and monitor the progress of their policy initiatives on the contribution of R&D and innovation alike towards national social and economic development.

It is therefore essential to measure Science, Technology, and Innovation- particularly R&D-, and its impact on the overall economic system, and the collection of quality statistics is critical to achieving the associated targets of the Sustainable Development Goals (SDGs). However, R&D statistics in developing countries have been scarce, particularly in Indonesia – hence BPS' initiatives in this space in recent years. Until the introduction of BPS' survey instrument, there has not been data to explain the characteristics of R&D in Indonesia, for example, the dynamics of R&D systems, R&D practices, behaviors and contributions. To produce R&D statistics, the Frascati Manual (FM) is used extensively in developing countries (including Indonesia) despite the fact that it was originally written for R&D surveys in OECD

member countries[2]. The FM is the most widely accepted international standard practice for R&D surveys[3].

Historically, the measurement of R&D in Indonesia has been done through conducting a sample survey; this systematic approach followed the GSBPM (Generic Statistical Business Process Model), consisting of the stages of specify needs, design, build, collect, process, analyze, disseminate, and evaluate. Despite the systematic approach, there are, however, still many weaknesses in measuring the R&D in Indonesia. Given this there was a need for a framework which used standardized concepts and methodology, which is fit for national purpose and internationally comparable, to explore current insights for evidence of contribution towards sustainable development[4]. The 2030 Agenda, adopted at the United Nations Sustainable Development Summit in September 2015, positioned R&D – one of important statistics in Science, Technology and Innovation (STI) - as integral elements of national sustainable development strategies.

This study highlights the numerous improvements made, but also limitations in current R&D measurement practices in Indonesia. It highlights, the issues and challenges that arose from data collection. It also examines the evidence contribution of R&D towards economic development of Indonesia in the Era of Revolution Industry 4.0 to support the Sustainable Development Goals.

III. Research and Development Concept

3.1. Defining R&D Concept- Frascati and Its Application in Indonesia

Research and experimental development (R&D) plays an important role in innovation processes and is a key factor in developing new competitiveness in a business. Identifying

[2] the methodology proposed by the Organization for Economic Co-operation and Development (OECD) in the Frascati Manual (FM)

[3] Measuring Research and Development in Developing Countries: Main Characteristics and Implications for the Frascati Manual; JACQUES GAILLARD; Science, Technology & Society 15:1 (2010)

[4] IATT Background Paper, Science, Technology and Innovation for SDGs Roadmaps, June 2018;

R&D in business needs firmed concept to enable capturing the R&D activities. Frascati Manual by Organization for Economic Co-operation and Development (OECD) has been the acknowledged worldwide standard for collecting and reporting internationally comparable statistics of R&D. Frascati manual defined R&D as “Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge (OECD, 2015, p.28).” According to this manual, there are five criteria which have to be fulfilled every time an R&D activity is undertaken; novel, creative, uncertain, systematic, transferable and/or reproducible.

Another concept from United Nations Conference on Trade and Development (UNCTAD, 2006) defines the concept as: “R&D consists of four types of activities: basic and applied research, and product and process development. Basic research is original experimental work without a specific commercial aim, frequently done by universities. Applied research is original experimental work with a specific aim. Product development is the improvement and extension of existing products. Process development is the creation of new or improved processes”.

In United States, The Financial Accounting Standards Board (FASB) Accounting Standards Codification (ASC) provides U.S. GAAP (Generally Accepted Accounting Principles) for businesses. ASC is organized by “topics” and Topic 730 is devoted to Research and Development (formerly covered in FASB Statement No. 2 “Accounting for Research and Development Costs”). The R&D definition in GAAP as following (National Science Foundation, 2018):

> “Research is planned search or critical investigation aimed at discovery of new knowledge with the hope that such knowledge will be useful in developing a new product or service (hereinafter 4 “product”) or a new process or technique (hereinafter

"process") or in bringing about a significant improvement to an existing product or process."

"Development is the translation of research findings or other knowledge into a plan or design for a new product or process or for a significant improvement to an existing product or process whether intended for sale or use. It includes the conceptual formulation, design, and testing of product alternatives, construction of prototypes, and operation of pilot plants."

Based on the literature, Indonesia mainly adopted the R&D concept from Frascati Manual. The NSO of Indonesia applied this definition in R&D Pilot Survey 2017 and R&D Survey 2018. R&D definition used by National Statistics Office (NSO) of Indonesia in developing R&D Statistics as following:

"Research and experimental development (R & D) are creative activities carried out systematically to increase knowledge and to find new applications of available knowledge." In order for an activity to be considered as a R & D activity it must fulfill: 1) Aim to get a new discovery/ new findings (novelty); 2) creative; 3) not routine; 4) systematic (planned, budgeted); and 5) can be transferred or reproduced (directs to results that allow it to be reproduced). All five criteria are to be met, at least in principle, every time an R&D activity is undertaken".

Ministry of Research, Technology, and Higher Education as the authorized government in developing R&D policy in Indonesia has a vision which has been conveyed in the National Research Master Plan for 2017-2045 is "Indonesia 2045 Competitive and Sovereign Based on Research".

R&D is also an important Sustainable Development Goals (SDG's) specifically, Target 9.5: Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers

per 1 million people and public and private research and development spending. There are two indicators in SDGs related to R&D: a) 9.5.1 Research and development expenditure as a proportion of GDP; b) 9.5.2 Researchers (in full-time equivalent) per million inhabitants.

R&D in Industrial Revolution 4.0

Over centuries, mankind has tried to improve the way in producing goods in the industry. There are four main paces in industry revolution, from the traditional technology to the modern technology. At the First Industrial Revolution, industries utilized water and steam power to mechanize production. At the Second, businesses created mass production by utilizing electric power. At the Third, industries tried to automate production by utilizing electronics and information technology. Now a Fourth Industrial Revolution is building on the Third which characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres (Schwab, 2016). A study in Switzerland by Delloit (2015) define fourth industrial revolution (industry 4.0) as “a further developmental stage in the organization and management of the entire value chain process involved in manufacturing industry”.

The fourth industrial revolution depends heavily on the technological capabilities of an industry. Industries those are ambitious to survive and excel in competition need to invest more to adapt a variety of new technologies in the industrial era 4.0. It is urgent to nurture trained individuals for technical development to respond to the Fourth Industrial Revolution, improve educational programs to foster project developers, and actively make research & development (R&D) investment for the education of such developers (Lee, et al, 2018).The Indonesian government through the Ministry of Industry realizes the importance of R & D in preparation for the era of Industry 4.0. To support industry 4.0, the Ministry of Industry revitalizes R & D and builds an Innovation Center with focus on 5 industry priority sectors,

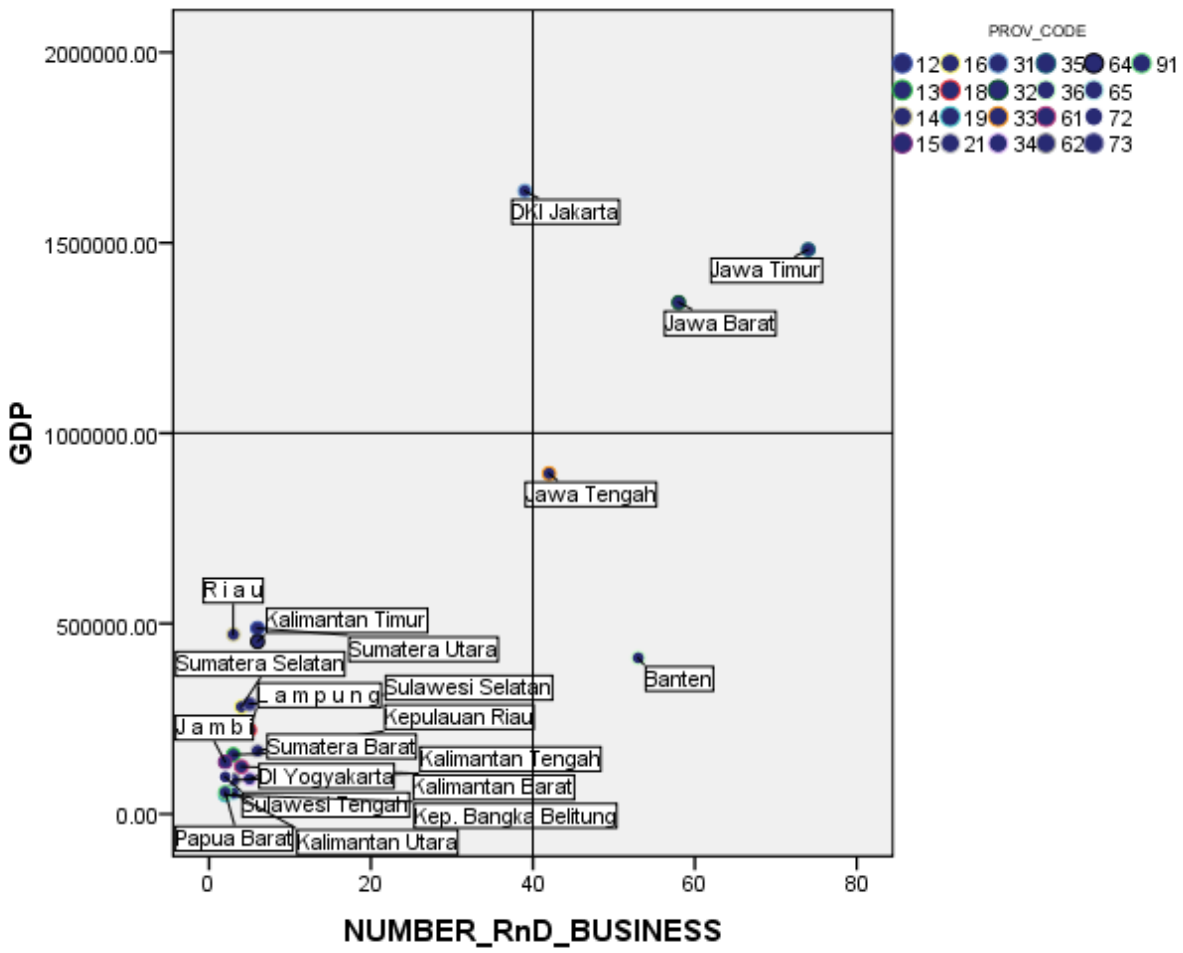
namely the food and beverage, chemical, textile, electronic and automotive industries (Ministry of industry, 2019).

3.2. Policy Imperatives of Measuring R&D

To formulate and conduct effective R&D strategies, policy makers need statistical evidence. Therefore, measuring R&D is to monitor the progress of national policy on R&D to enable national productivity, growth, and well-being. In Indonesia's case, data collection on R&D has increased in demand since the Government of Indonesia formulated a National Research Master Plan of Indonesia (NRMPI) 2017-2045. In the NRMPI, Indonesia set a target for GERD (Gross Expenditure R&D towards GDP (Gross Domestics Product) of 0.84 as well as a goal to have at least 16 researchers among ten-thousand inhabitants by 2020[5]. However, in Indonesia case, data on R&D is still limited. There was often been significant problems compiling the data due to a lack of coordination at the national level, a lack of cooperation by Public, Private and Higher Education sectors, and a generally conceptual understanding of the framework related to R&D statistics.

However, there is some evidence that has been used to monitor the implementation of policies on R&D, particularly related to growth, shown by .the relationship between GDP and the number of R&D businesses. Figure 1.1 shows that provinces with a lower number of R&D performing business generally have a lower level of GDP. This data has been used to determine that R&D policies should target certain provinces of Indonesia to accelerate growth and productivity. Moreover, measuring the level of R&D in Indonesia is very important, as its vital contribution to the Economic Development in the Era of Revolution Industry 4.0.

[5] Indonesia National Research Master Plan 2017-2045, page 47.



Picture 1.1: Number R&D Business and GDP, 2017.
Source: BPS - National Statistics Office of Indonesia, 2017

IV. Measuring R&D in Indonesia: Issues and Challenges

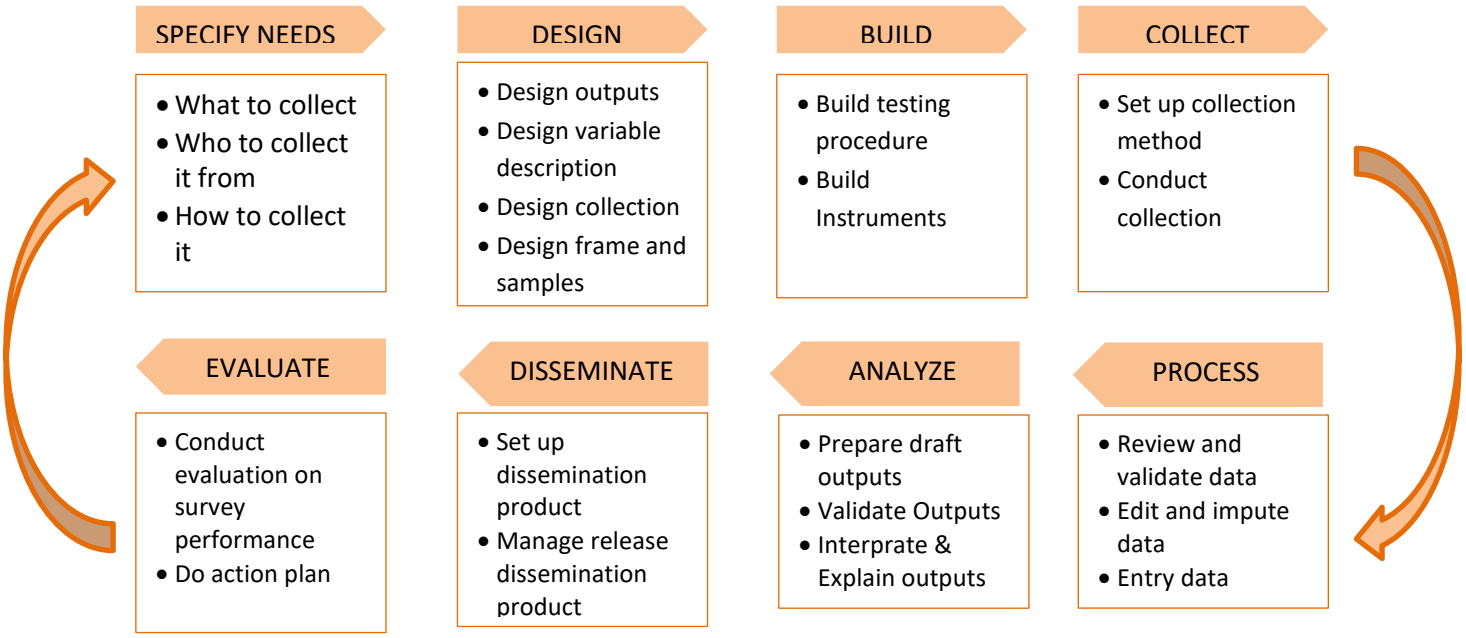
4.1 Process of Measuring R&D in Indonesia

Many regional neighboring countries have attempted to measure R&D, such as Singapore who held National Survey of R&D which is conducted and published annually by the Agency for Science, Technology, and Research. The approach is to survey all organizations that are known to perform R&D (A*STAR, 2015). Malaysia has also conducted a National Survey of R&D. Malaysia also built the Malaysian Research and Development Classification System (MRDCS) for classifying and describing research activities in Malaysia to the highest detail and accuracy. These classifications provide the basis for the

measurement and analysis of R&D activities and statistics that are useful guidelines to the government policy makers, industrialists and researchers. It is also a useful indicator on the direction of R&D and technological change. As technological advances become increasingly dynamic, there are no limitations to the introduction of new researchable areas (Malaysia Science and Technology Information Center, 2019).

In Indonesia's case, measuring R&D was conducted by BPS – National Statistics Office of Indonesia through Pilot Survey of R&D in Business Sector 2017, and as well as Survey of R&D in Business Sectors 2018. Developing R&D in Indonesia followed the Generic Statistical Business Process Model (GSBPM) by UNECE (2009) as follows:

Picture 1.2: GSBPM (Generic Statistical Business Process Model, 2017
Source: BPS – National Statistics Office, 2017



Picture 1.3: R&D Measurement Process based on GSBPM
Source: BPS – National Statistics Office, 2017

Using GSBPM as the basis for the process of measuring R&D in Indonesia was done to help ensure BPS achieved a good survey design and quality. When composing the form, BPS considered the aspects of "from art to science", the question development in the survey involved implementing aspects of psychology and sociology. The collection phase emphasized the importance of survey content development techniques prior to field enumeration. Pre-testing techniques aim to identify non-sampling errors and to suggest ways to improve or minimize the occurrence of these errors. It consisted of conceptual testing, cognitive testing, and observational testing[6].

In term of Survey methodology, due to the unavailability of a sampling frame, the Pilot Survey of R&D in Business sectors in 2017 applied purposive sampling. Data collection from selected businesses / companies was done through face-to-face interviews between

[6] Conceptual testing was conducted to help sharpen the concepts and definitions of the terms of variables will be used in the R&D survey questionnaire. Cognitive testing was aims to get feedback on conceptual understanding and language used in the R&D survey form. The observational test aims to accommodate input / recommendations from cognitive tests, by observing a respondent complete a draft self-administered questionnaire in a "live" situation.

enumerators and respondents. The sample size was 498 businesses in 9 provinces of Indonesia: Kepulauan Riau, DKI Jakarta, Jawa Barat, Jawa Tengah, Jawa Timur, Banten, Kalimantan Timur, Sulawesi Selatan, and Papua. Whereas the 2018 R&D Survey of the Business Sectors applied Stratification Sampling based on affirmative R&D responses from the Economic Census. In the Economic Census 2016, a question to identify R&D activities in a business/firm, based on the R&D Frascati Manual definition was used. The quality of this data as a basis of the frame is somewhat questionable. It was not easy to distinguish which businesses doing R&D activities and which one none in the enumeration reference period. Given this, even though the 2016 Economic Census resulted in about 4,780 businesses in Indonesia having performed R&D activities, it was still doubtful due to weaknesses of conceptual framework to define R&D activities in Business sectors in Indonesia.

Some key results from the Pilot Survey of R&D in Business Sector 2017 and the Survey of R&D in Business Sector 2018 can still be presented although the estimates are not yet representative of the national level:

- R&D expenditure by businesses reached USD 153.38 million, accounting for 0.018 percent of total R&D expenditure in 2016.
- Total research and development (R&D) expenditure of Business in 2017 is USD 190.84 million.
- R&D expenditure of Business sector as a proportion of GDP was 0.018 percent in 2017, and 0.02 in 2018.

Within this approached framework, some core indicators related to R&D activities can be measured, to support the Sustainable Development Goals (SDGs) Goal 9: “Build Resilient Infrastructure, Promote Inclusive and Sustainable Industrialization and Foster Innovation”. However, there are outstanding issues, either in terms of concepts, definitions, coverage, and method of data collection.

4.2 Issues and Challenges

The measurement of R&D in developing countries is generally challenging – not just in Indonesia – and establishing a benchmark to measure R&D is still difficult due to a range of obstacles, both conceptual and practical**.** Moreover**,** R&D is a key to promoting digital economy in the era of revolution industry 4.0.

The issues and challenges in measuring R&D in Indonesia can be summarized based on our experience in 2017 and 2018 as presented below:

- ✓ **Hard Concept and Definition of R&D**

To produce R&D statistics, the methodology proposed by the Organization for Economic Co-operation and Development (OECD) in the Frascati Manual (FM) is used extensively in developing countries despite the fact that it was originally written for R&D surveys in OECD member countries. This confirms the FM as the most widely accepted international standard practice for R&D surveys[7].

Based on Indonesia's experience, the concept of R&D from Frascati Manual is quite hard. In many developing countries, the business sector performs much less R&D than the government and higher education (public) sectors. Likewise in Indonesia, businesses who perform R&D are mainly only Medium and Large Businesses. Among the five criteria required for an activity to be deemed R&D, only very small number of business satisfied the criteria, (almost none in micro and small businesses).

- ✓ **No Sampling Frame**

Lack of information about R&D activities by businesses in Indonesia impacted the sampling frame for R&D data collection. R&D Pilot Survey 2017 was conducted based on purposive sampling with information obtained from NSO provincial offices about businesses who were most likely to conduct R&D. While for the R&D Survey 2018, the sampling frame was built from Economic Census 2016. In the Economic Census, businesses were asked

[7] UIS UNESCO, *Measuring R&D: Challenges Faces by Developing Countries*, Technical Paper No.5,page 4, 2010

whether they conducted R&D or not. From the question, the sampling frame for R&D Survey was available and the sample was taken with probability sampling. However, this sampling frame was still very weak because of some issues: 1) the R&D concept was not properly provided; and 2) the enumerator did not properly understanding the concept, considering that Economic Census was a big event which held manually-interviewed face to face with many questions and given short time. This is proven by the results from R&D Survey 2018 that many businesses which stated conducting R&D in 2016 are not really conducting R&D in 2016 and 2017.

- ✓ **R&D statistical systems need to be strengthened**

To conduct R&D survey in Indonesia is very challenging due to weaknesses of R&D statistical systems. The multiple measurement efforts sometimes duplicate, but not complement each other. Establishing a sound and sustainable R&D statistical system requires dedicated political support as well as a predictable budget, infrastructure, a stable staff complement (knowledge management) and the provision for continuous training[8].

In the case of Indonesia, BPS-Statistics Indonesia is not the only institution who is responsible for the R&D Surveys. Ministry of Research, Technology, and Higher Education, and LIPI also conduct a survey of R&D. Problem occurs when the result of R&D survey shows inconsistency and the coverage of R&D was also incomplete. Ideally, the responsibility for the surveys should remain vested with a dedicated agency for periods in excess of five years so that methodological stability may be attained. Migration of responsibility for the survey carries the risk of inconsistency[9]. Irrespective of where responsibility for the survey is placed, the necessary legal framework to strengthen R&D statistical system and as well as to ensure survey participation and the confidentiality of data must be enacted.

[8] UIS UNESCO, *Measuring R&D: Challenges Faces by Developing Countries*, Technical Paper No.5,page 29, 2010
[9] UIS UNESCO, *Measuring R&D: Challenges Faces by Developing Countries*, Technical Paper No.5,page 30, 2010

The other challenges to measuring R&D in Indonesia conducted by BPS – National Statistics Office of Indonesia is to cover R&D activities in all sectors, not only at Business sectors, but also including Government, and Higher Education Sectors. The coverage of R&D activities in Public and Higher Education sectors should be census basis, but in terms of data collection of R&D in business sectors may still on a survey basis. Moreover, the geographical difficulties in Indonesia are also a challenge in carrying out R&D measurement, as Indonesia is an archipelago country with a very large population. In addition, the limitation of training enumerators is also a challenge to produce quality R&D statistics. The other important challenge is "go digital" in doing the Survey of R&D. As this is in the era of revolution industry 4.0, all data collection procedure should be not manually, shifting to "go digital" enumeration by using devices penetration.

V. Conclusion

This paper has intended to highlight some of the issues and challenges faced by Indonesia in measuring R&D in business sectors, and utilizing that measurement to support SDGs. Based on these explanations, it may be concluded that:

(a) It is essential to measure R&D and its impact on the overall economic system, and the collection of quality statistics is critical to achieving the associated targets of the Sustainable Development Goals (SDGs).

(b) Within the framework, some core indicators related to R&D activities can be measured, to support the Sustainable Development Goals (SDGs) Goal 9: "Build Resilient Infrastructure, Promote Inclusive and Sustainable Industrialization and Foster Innovation". Besides to support SDGs target, the R&D activities may promote the intensity use of technology digital which is one of characteristics business environments todays in the Era of Industry Revolution 4.0.

(c) Measuring R&D was conducted by BPS – National Statistics Office of Indonesia through Pilot Survey of R&D in Business Sector 2017, and as well as Survey of R&D in Business Sectors 2018.

(d) Establishing a benchmark to measure R&D is still difficult due to a range of obstacles, both conceptual and practical. Some of the issues are conceptual, definitional, no sampling frame, and requirements around statistical system strengthening.

(e) Other challenges to measuring R&D in Indonesia are using a census basis for R&D in Public sectors and Higher Education sectors, whereas in Business sectors may still at a survey basis. In addition, the geographical difficulties in Indonesia and the limitation of training enumerators is also a challenge to produce quality R&D statistics. Moreover, data collection procedure should be not manually, shifting to “go digital” enumeration by using devices penetration.

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